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VARIABLE RESISTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a variable resistor used in industrial equipment such as a hearing aid, a measuring instrument, communications equipment, a sensor, or other such electronic apparatus, and in particular, the present invention relates to a miniaturized variable resistor.

2. Description of the Related Art

In recent years, reduction in the size and the weight of electronic equipment has been required, and circuit components provided within electronic equipment are also required to be small-sized components. For a variable

variable resistor having a diameter or side length of about 2 mm has been used. A variable resistor requires a slider which is a spring component. However, the miniaturization of the slider makes it difficult to achieve good electrical contact and sliding characteristics.

In Figs. 1 and 2, a conventional ultra-miniature

variable resistor having a structure in which a shaft 2, a rotor 3, a slider 4, and a substrate 5 are provided in a case 1, and which is sealed by filling a sealing resin 6 such as epoxy resin in the bottom opening of the case 1, is shown. Here, lead terminals 71, 72, and 73 are fixed on the substrate 5. The lead terminals are electrically connected to both sides of an arcuate resistor 51 and a collector electrode 52, respectively.

As shown in Fig. 3, the slider 4 is defined by a thin metallic plate having a annular arm portion 41 making sliding contact with the arcuate resistor 51 of the substrate 5, and an I-shaped arm 42 arranged to contact the collector electrode 52 of the substrate 5. The annular arm portion 41 is bent up at the portion corresponding to the diameter, and the I-shaped arm portion 42 extends in a direction that is substantially perpendicular to the bent-up line of the annular arm portion 41, and is located inside of the annular arm portion 41. In the left side view of Fig. 3,

two-dot chain line designates the state without a load. In the slider 4, a pair of through holes 44 for fitting to the protrusions 31 (see Fig. 4) of the rotor 3 are provided at bilaterally symmetrical positions around the I-shaped arm portion 42. The slider 4 is mounted on the rotor 3 so as to be rotatable together with the rotor 3, by fitting the

protrusions into the through holes 44, and then crushing the protrusions 31 by weld-caulking.

As shown in Fig. 5, in the variable resistor having the above-described features, when the substrate is mounted in the variable resistor, both of the annular arm portion 41 and the I-shaped arm portion 42 are subjected to a load. As a result, a moment M in the backward-tilting direction of the slider 4 occurs with respect to the slider 4 around the root of the bent up portion of the annular arm portion 41, as a fulcrum (see Fig. 5B). Once a backward-tilting of the slider 4 occurs, a problem arises that the contact between the resistor 51 and the annular arm portion 41, and the contact between the collector electrode 52 and the I-shaped arm portion 42 become unstable, resulting in a reduction in the reliability.

In order to prevent the slider 4 from backwardly tilting, the protrusions 31 of the rotor 3 are weld-caulked. However, since the two protrusions 31 to be weld-caulked are

annular arm portion 41, the distance between the protrusions 31 and the bending-up line 43 defining the fulcrum is small, so that the backward-tilting of the slider 4 cannot be effectively prevented. Furthermore, in the case of very small components, protrusions 31 having a sufficient size cannot be formed on the rotor 3, and also welding work is

very difficult. For example, when the diameter of the slider 4 is 1.5 mm, the diameter of the protrusions needs to be about 0.2 mm. The process of welding such a small protrusions 31 is thus very difficult, and a desired fixing strength cannot be reliably achieved even though welding is executed.

SUMMARY OF THE INVENTION

In order to overcome the problems described above, preferred embodiments of the present invention provide a variable resistor arranged to effectively and reliably prevent a slider from backwardly tilting toward a rotor, and thereby maintaining stable contact between the slider and a substrate.

According to one preferred embodiment of the present invention, a variable resistor includes a case, a rotor rotatably accommodated in the case, the rotor being rotationally operated from the outside of the case, a

collector electrode at an approximate central portion of the surface thereof, and having an arcuate resistor disposed outside of the collector electrode so as to be substantially concentric therewith, a slider mounted on the rotor so as to be rotatable together with the rotor, the slider having an annular arm portion arranged to achieve sliding contact with

the arcuate resistor on the substrate, and having a substantially I-shaped arm portion arranged to contact the collector electrode, and a base portion that is integral with the slider, the base portion being coupled at one end thereof with the annular arm portion and the substantially I-shaped arm portion by a folded-back structure, and extending up to the vicinity of the position corresponding to the tip portion of the annular arm portion, the rear surface of the base portion being supported by the rotor. In this variable resistor, the annular arm portion is bent up at the portion corresponding to the diameter or at the portion in the vicinity thereof. The substantially I-shaped arm portion extends in a direction that is substantially perpendicular to the bent-up line of the annular arm portion, and is located inside of the annular arm portion.

The annular arm portion of the slider rotates and makes sliding contact with the arcuate resistor of the substrate around the substantially I-shaped arm portion as a fulcrum. In such an operational state in which both of the annular arm portion and the substantially I-shaped arm portion are under a load, a moment in the backward-tilting direction acts on the slider around the root of the bent up portion of the annular arm portion, as a fulcrum. In the slider in accordance with a preferred embodiment of the

present invention, however, a base portion is integral with the slider, and the base portion is coupled with the annular arm portion and the substantially I-shaped arm portion by the folded-back structure, and the base portion extends up to the vicinity of the position corresponding to the tip portion of the annular arm portion. With this configuration, the base portion supports the moment in the backward-tilting direction, and can surely prevent the slider from backwardly tilting. This stabilizes the contact between the resistor and the annular arm portion, and that between the collector electrode and the substantially I-shaped arm portion, which leads to an improvement in the reliability.

Preferably, the annular arm portion, the substantially I-shaped arm portion, and the base portion are coupled such that the base portion is folded back, and the annular arm portion, the substantially I-shaped arm portion, and the base portion are closely contacted by the folded-back structure. Thereby, the height dimension of the slider can

structures of the prior art. This allows variable resistors in preferred embodiments of the present invention to be more low-profile.

It is preferable that the substantially I-shaped arm portion is raised without folding the substantially I-shaped arm portion by folding a portion of the folded-back portion

between the annular arm portion and the base portion in the direction opposite to the bending-up direction of the annular arm portion. In the slider having a conventional structure, since the substantially I-shaped arm portion is folded and raised, work-hardening occurs in the folded portion under the influence of bending work, with the result that the elastic region in the substantially I-shaped arm portion, that is, the effective spring length L_1 thereof (see Fig. 5A) becomes smaller. This creates a problem that the contact pressure between the substantially I-shaped arm portion and the collector electrode becomes greater than is needed. On the other hand, in the above-described construction in accordance with a preferred embodiment of the present invention, since the substantially I-shaped arm portion is substantially linear, and the raising of the root portion of the substantially I-shaped arm portion by folding is not done, work-hardening due to bending work does not occur, and the stress with respect to the load disperses

allows a wider elastic region to be available. That is, it is possible to make the effective spring length longer, and to set the contact pressure between the substantially I-shaped arm portion and the collector electrode to an appropriate value.

Preferably, a pair of through holes for fitting to the

protrusions of the rotor are provided on the opposite surfaces of the annular arm portion and the base portion in the vicinity of the folded-back structure, and substantially at bilaterally symmetrical positions around the substantially I-shaped arm portion. Specifically, the through holes are preferably arranged at common positions relative to the annular arm portion and the base portion, and the insertion of the protrusions of the rotor into the through holes of the slider prevents the slider from slipping with respect to the rotor, when the rotor is rotated. In this case, since the slider is prevented from backwardly tilting, there is no need to fix the protrusions by weld-caulking. Also, since the load applied on the protrusions is small, even such thin protrusions do not cause any problem.

The above-described variable resistor in accordance with a preferred embodiment of the present invention may be applied to hearing aids. In hearing aids, variable resistors

accordance with the miniaturization of hearing aids, miniature size variable resistors have been required. Use of a variable resistor of miniature size and having stable characteristics allows the reliability of a hearing aid to be greatly improved.

In the present invention, the method for attaching the

slider and rotor is not limited to the conventional method in which the protrusions are weld-caulked. This is because the slider would not slip with respect to the rotor by virtue of the spring forces of the arm portions if only the rotation of the base portion with respect to the rotor is stopped.

The above and other characteristics, elements, features and advantages of the present invention will be apparent from the following detailed description of preferred embodiments of the invention in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view showing a conventional variable resistor.

Fig. 2 is an exploded perspective view showing the variable resistor shown in Fig. 1.

Fig. 3 illustrates a left-side view, a front view, and

view, each showing the slider included in the variable resistor in Fig. 1.

Fig. 4 is a perspective view showing the slider and rotor used in the variable resistor shown in Fig. 1, as viewed from the rear side.

Figs. 5A and 5B are partially sectional views

illustrating the variable resistor before and after the substrate is built in the variable resistor shown in Fig. 1, respectively.

Fig. 6 is a cross-sectional view illustrating an example of a variable resistor in accordance with a preferred embodiment of the present invention.

Fig. 7 is an exploded perspective view illustrating the variable resistor shown in Fig. 6.

Fig. 8 illustrates a left side view, a front view, a cross-sectional view taken along the line B-B in the front view, and a rear elevation each showing the slider used in the variable resistor in Fig. 6.

Fig. 9 is a front development illustrating the slider shown in Fig. 8.

Fig. 10 is a perspective view illustrating the slider and rotor used in the variable resistor shown in Fig. 6, as viewed from the rear side.

Figs. 11A and 11B are partially sectional views

substrate is built in the variable resistor shown in Fig. 6, respectively.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figs. 6 through 11 illustrate an example of a variable resistor in accordance a preferred embodiment of the present

invention. This example is used for, for example, a hearing aid.

Since this variable resistor has the same structure as the variable resistor shown in Figs. 1 through 5, except for the slider 8, the same elements and parts as shown in Figs. 1 through 5 are identified by the same reference numerals to avoid repetitive description.

A case 1 is molded in one piece so as to have a substantially cylindrical shape using a heat-resistant thermoplastic resin or thermosetting resin, in order to resist the heating generated by soldering and to allow a stable operation in a high-temperature atmosphere.

A substantially circular opening 11 is provided in the top surface of the case 1, and a stopper portion 12 is arranged to protrude from the inner peripheral surface thereof. A stopper portion 21 for a shaft 2 is inserted into the opening 11, and the rotational angle of the shaft 2 is regulated by abutting the stopper portion 21 of the shaft

also preferably made of the same material as the case 1, but may alternatively be formed of a metal. On the top end surface of the shaft 2, a tool engaging groove 22 is arranged to extend in the diametric direction. A thin shaft portion 23 is arranged to protrude from the bottom end surface of the shaft 2. A substantially cylindrical internal

space 13 accommodating the rotor 3, the slider 8, and the substrate 5 is provided in the lower portion of the case 1. The substrate 5 is fitted to the lower-end opening portion 14 of the case 1. The substrate 5 is prevented from slipping off by inwardly thermal-caulking the end portion of this opening portion. A sealing resin is filled into the recess defined by the lower-end opening portion 14 and the substrate 5 and is arranged to seal the recess.

The rotor 3 is also molded in one piece into a disk shape using the same material as the case 1, and a hole 32 to be fitted into the shaft portion 23 of the shaft 2 is provided at the approximate center of the rotor. The shaft 2 and the rotor 3 are integrated, by inserting the shaft portion 23 of the shaft 2 into the hole 32, and thermal-caulking the tip thereof. As coupling member for the shaft 2 and rotor 3, for example, a claw portion for preventing the shaft portion 23 from slipping off, may be provided at the tip of the shaft portion 23, in place of the method in which protrusions 31 are provided on the bottom surface of the rotor 3 for preventing the slipping rotation of the slider 8 with respect to the rotor 3.

The substrate 5 defines a disk to be fitted into the lower-end opening 14 of the case 1, and is molded integrally using the same material as the case 1. A through hole is

provided at the approximate center of the surface of the substrate 5, and the upper end of the lead terminal 73 fitted into the approximately central through hole is exposed on the surface of the substrate 5, constituting a collector electrode 52. An arcuate resistor 51 around the collector electrode 52 is provided on the surface of the substrate 5. Through holes are also provided in both ends of this resistor 51, and the lead terminals 71 and 72 inserted into these through holes are connected to both ends of the resistor 51. Meanwhile, Figs. 6 and 7 show an example of a lead terminal type variable resistor in which the lead terminals 71 through 73 are inserted into the through holes in the substrate 5, but the type of variable resistor is not particularly limited to this type. The variable resistor in accordance with various preferred embodiments of the present invention may be constructed as a surface-mount type omitting the lead terminals 71-73.

The slider 8 is preferably made of a conductive thin

precious metal based alloy, or other suitable material having good spring property, and is subjected to surface processing using a precious metal or other suitable material, as appropriate. As shown in Fig. 8, in the slider 8, an annular arm portion 81, an substantially I-shaped arm portion 82, and a base portion 83 are stamped out from one

metallic plate, which are connected together. The annular arm portion 81, substantially I-shaped arm portion 82, and base portion 83 are folded back in a closely contacted state at the coupling portion 84 defining a boundary. The annular arm portion 81 is bent up along the bending-up line 85 in the diametric direction, and a sliding contact 81a for making sliding contact with the arcuate resistor 51 of the substrate 5, is arranged to protrude from the tip portion of the annular arm portion 81. The substantially I-shaped arm portion 82 extends in a direction that is substantially perpendicular to the bending-up line 85 of the annular arm portion 81, and is a linear arm located inside the annular arm portion 81. A contact member 82a arranged to contact the collector electrode 52 is arranged to protrude from the tip of the substantially I-shaped arm portion 82.

The base portion 83 is constructed as a disk having substantially the same diameter as the annular arm portion 81. The base portion 83 extends up to the vicinity of the

portion 81 where the sliding contact member 81a is provided. The rear surface of the base portion 83 is supported on the surface of the rotor 3. A fold-back portion 86 near the coupling portion 84 where the base portion and the annular and I-shaped arm portions are folded and closely contacted, is folded in the direction opposite to the bending-up

direction of the annular arm portion 81, and the substantially I-shaped arm portion 82 is not folded, but is raised. That is, the substantially I-shaped arm portion 82 extends linearly from the folded-back point at the coupling portion 84. Corresponding to this fold-back portion 86, an inclined surface 33 (see Fig. 10) is defined on the bottom surface of the rotor 3. A pair of through holes 87 and 88 for fitting to the protrusions 31 of the rotor 3 are provided on the closely contacted surfaces of the annular arm portion 81 and the base portion 83, at the area except the bending-up line 85. The through holes 87 and 88 are arranged substantially at bilaterally symmetrical positions around the substantially I-shaped arm portion 82. After the protrusions 31 have been inserted into the through holes 87 and 88, they are not required to be weld-caulked.

As described above, since the substantially I-shaped arm portion 82 extends linearly from the folded-back point at the coupling portion 84, the elastic region of the

shown in Fig. 11, that is, the effective spring length L_2 thereof becomes larger. This allows the contact pressure between the substantially I-shaped arm portion 82 and the collector electrode 52 to be set to an appropriate value.

Here, the effective spring length of the annular arm portion 81 is the distance from the bending-up line 85 to

the sliding contact 81a.

In this preferred embodiment of the present invention, since the effective spring length of the annular arm portion 81 and that of the substantially I-shaped arm portion 82 of the slider 8 are substantially the same, the spring elasticity of the two arm portions 81 and 82 are also preferably substantially the same.

As shown in Fig. 11, when the substrate 5 is assembled into the case 1, since both of the annular arm portion 81 and the substantially I-shaped arm portion 82 are subjected to a load, a moment in the backward-tilting direction occurs with respect to the slider 8 around the bending-up line 85 of the annular arm portion 81, as a fulcrum (see Fig. 8B). However, since the slider 8 is integral with the base portion 83, and the rear surface of this base portion 83 is supported by the rotor 3, it is possible to stably support the slider 8 with respect to the moment M, and to reliably prevent the slider 8 from backwardly tilting. This

annular arm portion 81, and that between the collector electrode 52 and the substantially I-shaped arm portion 82, which greatly improves reliability.

The protrusions 31, which are fitted in the through holes 87 and 88, have no need to prevent the slider 8 from backwardly tilting, but have only to prevent the slipping

rotation of the slider 8 with respect to the rotor 3. The protrusions 31, therefore, are not required to be weld-caulked. Also, since the protrusions 31 are subjected to only a small load, they can prevent a damage of the slider even if the protrusions 31 are small.

The present invention is not limited to the above-described preferred embodiments. The shape of the base portion 83 is not limited to a disk shape. Alternatively, any shape, such as an annular shape, a cross shape, or other shapes may be used. Corresponding to this, an engaging portion for stopping the rotation of the base portion 83 may also be provided on the bottom surface of the rotor 3. Any shape which meets the condition that the base portion 83 is supported by the rotor 3 over a wide region in the longitudinal direction of the annular arm portion 81, and which can support a moment M in the backward-tilting direction applied to the slider 8, may be used.

Also, although the annular arm portion 81, the

83 are folded back in a closely contacted state, they may be folded back without being closely contacted.

Furthermore, the outer shape of the case 1 is not limited to a substantially cylindrical shape, but it may be a square cylindrical shape or other shape. In this case, it is preferable that the outer shape of the substrate 5 be not

a disk-like shape, but have a square-plate shape.

In the present invention, the shape of the annular arm portion of the slider is not limited to an annular shape in the strict sense. The term "annular shape" used herein is a concept including similar shapes. It is possible that the shape of the annular arm portion of the slider constitutes a closed loop. Also, the shape of the substantially I-shaped arm portion is not limited to an I-shaped configuration in the strict sense, but has only to be substantially linear.

As is evident from the above description, in accordance with preferred embodiments of the present invention, in the state in which the annular arm portion and the substantially I-shaped arm portion are in pressure contact with the substrate, a moment in the backward-tilting direction acts on the slider around the root of the bent up portion of the annular arm portion, as a fulcrum, but in the slider, since a base portion which is coupled with the annular arm portion and the substantially I-shaped arm

slider, and the base portion extends up to the vicinity of the position corresponding to the tip portion of the annular arm portion, as well as the rear surface of the base portion is supported by the rotor, the base portion supports the moment in the backward-tilting direction, and can surely prevent the slider from backwardly tilting. This stabilizes

the contact between the resistor and the annular arm portion, and that between the collector electrode and the substantially I-shaped arm portion, which leads to greatly improved reliability.

Moreover, in accordance with various preferred embodiments of the present invention, since the slider does not necessarily need to be fixed with respect to the rotor by weld-caulking, unlike the conventional art, and only the rotation of the slider with respect to the rotor needs to be stopped by any engaging structure, it is possible to simplify the assembling work.

While the present invention has been described with reference to preferred embodiments thereof, many modifications may be applied in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.